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Dietary preferences of the black-gloved wallaby (*Macropus irma*) and the western grey kangaroo (*M. fuliginosus*) in Whiteman Park, Perth, Western Australia

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Abstract

Epidermal tissue trace analyses of faecal material indicated that the native banksia woodlands and adjacent managed grass areas of the Perth metropolitan Whiteman Park provided a varied diet for the black-gloved wallaby (*Macropus irma*) and the western grey kangaroo (*M. fuliginosus*). Black-gloved wallabies fed on a range of species, with a total of 29 included in the diet. *Cynodon dactylon*, the dominant grass of the lawn areas, *Carpobrotus edulis*, a succulent species in roadside disturbed sites, and the native cycad, *Macrozamia riedlei*, generally of the native woodland, were the three species most frequently consumed.

The diet of the western grey kangaroo included 25 species, with two grasses, *Cynodon dactylon* and *Ehrharta calycina*, the most frequently consumed. Western grey kangaroos showed a preference for monocotyledons, but dicotyledons also were common in the diet. Comparisons of thirteen chemical constituents and five morphological features of chosen and avoided plant species did not explain diet choice. A wide overlap of consumed plant species between the two herbivores indicated that competition for food resources was possible. However, the polyphagous diet for both species indicates that the ability to switch diet preferences probably precludes the competitive exclusion of one by the other.

Analysis of the epidermal material of the stomach, the small intestine, and the large intestine and colon indicated that the digestive system of the black-gloved wallaby did not completely remove plant epidermal traces of any of the ingested species. Therefore, the acid digestion technique used for faecal pellet analysis potentially indicates all the species consumed by the animal.

Retention of the mosaic of natural banksia woodland cover with adjacent areas of watered lawn should benefit the limited population of black-gloved wallabies in Whiteman Park. At present the population of western grey kangaroos is not large enough to consume enough material to affect either the population of black-gloved wallabies or the structural elements of the vegetation of Whiteman Park.

Introduction

Management programs are becoming increasingly important in the maintenance of wild animal populations. Land clearing and expansion of urban areas has resulted in small isolated remnants of bushland. Such 'remnant islands' are difficult for mammal populations to recolonise. Whiteman Park, in north-east metropolitan Perth, is such an 'island'. Whiteman Park is presently inhabited by two Macropodidae species, the black-gloved wallaby (*Macropus irma*) and the western grey kangaroo (*M. fuliginosus*). The population of black-gloved wallabies in the Park has been estimated at 40 animals (Arnold *et al.* 1991). The population of western grey kangaroos is much higher, at between 550 (Arnold *et al.* 1991) and 1000 animals (H Gratte, *pers comm*). Maintenance of these animals in the park is a priority, but little is known of their dietary preferences or the potential that one species might require the same resources and exclude the other.

Because of the low numbers of black-gloved wallabies in Whiteman Park, a non-destructive method of determining their dietary preferences was required. Procedures used to estimate the botanical composition of herbivore diets include direct observation, utilisation techniques, analysis of mouth contents, fistula techniques, stomach analysis, and faecal analysis. Certain procedures are more useful than others, but each has important limitations. In this instance, faecal analysis was the preferred technique for these nocturnal macropods that often show severe stress when trapped. One road-killed black-gloved wallaby, however, afforded the opportunity to analyse digestive system contents and to provide a 'control' to the faecal pellet dietary samples.

The objectives of this study were to determine the plant species consumed by the black-gloved wallaby and the western grey kangaroo, to assess characteristics of favoured plants, and to determine the potential for resource competition between these two marsupial herbivores in the confined area of Whiteman Park.

Materials and Methods

Study site

Whiteman Park, comprising 2600 ha of natural bush and pasture, is situated approximately 20 km north-east of the central business district of Perth. The park is situated on rolling sand dunes of the Bassendean soil association (Bettenay *et al.* 1960) over a portion of the important ground-water aquifer, the Gnangara Mound, that serves the metropolitan water supply (Anon 1992). The vegetation is a mixture of low woodland of *Banksia attenuata*, *B. menziesii* and *Eucalyptus todtiana* on upper slopes, grading through a taller woodland dominated by *E. marginata*, *E. calophylla* and *B. ilicifolia* to moist lowlands where a woodland of *Melaleuca preissiana* and *B. littoralis* occurs (Anon 1989). Stream margins in the southern end of the Park harbour an open forest dominated by *E. rudis* and *M. rhaphiophylla*.

Mammal study species

The black-gloved wallaby is a small wallaby (up to 9 kg), which is reported to graze rather than browse, and prefers a habitat of open forest or woodland (Christensen 1983). Due to its trap-shy nature and difficulty in handling, the black-gloved wallaby has rarely been studied. However, Shepherd *et al.* (1997) documented that the black-gloved wallabies in the Perup region of the southern jarrah forest consume at least 21 different plant species. Christensen (1983) also reported that they appear to be able to survive without free water. The black-gloved wallaby adds to the conservation value of Whiteman Park, especially since it is the nearest relative to the now extinct toolache wallaby (*Macropus greyi*). Although still common in a number of jarrah forest regions, the black-gloved wallaby is rare in the greater Perth urban region.

The western grey kangaroo is larger than the black-gloved wallaby, with males reaching 54 kg (Poole 1983). The western grey kangaroo both grazes and browses, and its diet has previously been shown to include a wide range of plant species and life-form types (Halford *et al.* 1984b; Priddel 1986; Bell 1994). Western grey kangaroos in a region of mixed wandoo-pasture country near Bakers Hill fed both on pasture species and a range of native plant species with some indication that nitrogen-rich legume species were selected in percentages greater than the percentages found as vegetative cover (Halford *et al.* 1984b). Western grey kangaroos in the Perup region of the southern jarrah forest consumed at least 32 different plant species, and marsupial herbivores appear to have the capacity to significantly reduce plant cover by their grazing pressure (Shepherd *et al.* 1997).

Plant resources

The detailed documentation of available plant resources for the two herbivore species was carried out in an area of approximately 700 ha in the northern region of Whiteman Park, where both marsupial herbivores have been observed. Detailed plant resource investigations were centred on three sites and covered a range of habitats. Site 1 was directly north and north east of the archery range parking lot. Site 2 included the archery range and the bushland to its east. Site 3 was approximately 300 m north-east of the International Trap and Skeet Shooting Complex. At each study site, percentage cover for each plant species was estimated for ten 2 m × 2 m quadrats placed along a randomly selected 20 m transect. Mean percentage cover and frequency of occurrence of each plant species were determined by combining the data for all three study transects, as the home ranges of both species would be larger than any one single site.

Fresh material was collected for moisture content, ash content and morphological characteristics for all plant species. It was stored in plastic bags inside an ice-filled cooler chest and returned to the laboratory within 2-3 h. Approximately 1 to 5 g of fresh leaf material was weighed, placed in paper bags, oven dried at 60 °C for 48 h, and re-weighed to determine percentage moisture content. Ash content was determined using dried plant material fired in a muffle furnace at 550 °C for 2 h. Dried leaf material from 82 plant species was analysed for 13 chemical constituents using flame spectrophotometry (CSBP & Farmers Ltd, Bayswater, Western Australia). Morphological characteristics of leaves from each plant species in the study area were determined from dried specimens. In plants with leaves absent or reduced, the morphological characteristics of stems or branches were determined. Five characteristics thought to influence feeding choice were summarised into the following categories;

1) apex type described the shape of the apices of leaves or branches/stems;
2) apex hardness separated all spine-tipped apices from soft-tipped, rounded, square-tipped and indented-tipped apices;
3) glands were noted as either present or absent;
4) leaf consistency scored as succulent, mesophyll, semi-sclerophyll or sclerophyll; and
5) both adaxial and abaxial tomentosity of leaves scored as either low, medium or highly pubescent or non-hairy.

These characteristics of plant species subsequently confirmed by faecal analysis as food resource species were compared to those of species not in faecal pellets using unpaired, two-tailed t-tests and coded chi-square tests. Such tests identify deviations from random and, therefore, can be used to determine if diet selection is occurring.

Epidermal reference collection

All plant species were collected at the study sites during the early autumn. Leaf material was used for the epidermal tissue reference collection for most species (see Halford *et al.* 1984a). For plants with phyllodes, cladodes or very reduced leaves, the petioles, stems, or branch materials (the materials that are potentially available as food for herbivores), were used for the epidermal reference collection.

Two methods were used to separate the epidermal material from the underlying tissues. The first, a modification of Jain (1976), involved placing 5 mm × 5 mm squares, or whole small leaves, in glass vials with 50% glacial acetic acid. The vials were placed in a water bath at 80 °C for 24-48 h, depending on the sclerophyllous nature of the material. On removal from the water bath, the plant material was washed with water and the remaining fibrous tissue was removed under a dissecting microscope using tweezers, dissecting needles and scalpel blades. The epidermal material was then dehydrated through a series of ethanol solutions to 95% and stained with 0.5% gentian violet in 95% ethanol for 48 h. The stained material was then rinsed in absolute alcohol and mounted in Eukitt®. The second technique, generally used for thicker material, employed a method similar to that used by Storr (1961). Leaf material was placed in vials and covered with 10% chromic acid and 10% nitric acid, and boiled in an acid digestion heating block at 115 °C for 20-25 min. The tissue was then rinsed in 0.1 M KOH and the epidermal material was peeled off using tweezers and dissecting needles. The epidermal material was then dehydrated, stained and mounted as before.

Epidermal preparations were drawn to provide a visual record of the important characteristics of each plant species of the area.

Faecal sample collection and preparation

There was little difficulty in discriminating between the faecal pellets of black-gloved wallabies and western grey kangaroos. Faecal pellets of the former were smaller, round to oval, and pinched at the ends. Pellets of the latter were larger and at times almost cubic in shape. Fresh pellets were collected on a single day during each of the four seasons from the three vegetation study sites. Where there was more than one pellet in a deposit, only one was collected.

For each season, one pellet from each study site for each of the herbivores was randomly selected for fragment identification. Pellets were thoroughly dried, broken apart using tweezers, placed in a test tube and covered with 20 ml of equal parts 10% chromic acid and 10% nitric acid. The test tubes were placed in the acid digestion block in a fume hood and boiled at 115 °C for 20-25 min. The material was allowed to cool to room temperature before being filtered through a buchner funnel and Whatman No 10 filter paper with several washes of 0.1 M KOH. The filtrate was then collected and stained with 0.5% gentian violet in 95% alcohol for 48 h. After staining, the filtrate was passed through a 0.5 mm sieve and the remaining material was washed several times with 70% alcohol to remove excess stain. The tissue was placed in 95% alcohol in a glass petri dish and viewed through a dissection microscope at 6× to 30× magnification. Different species could generally be identified using the dissection microscope at its highest magnification. In some cases, a fragment was washed in absolute alcohol, mounted and viewed under a binocular microscope.

These epidermal fragments from faeces were then compared to the drawings of the epidermal reference collection and identification was confirmed by comparing the slide of the faecal epidermal fragment to the original plant voucher collection slide. Once a species had been positively identified, the proportion of each plant species in each pellet was subjectively determined as rare, common or abundant.

Black-gloved wallaby digestive tract contents

The carcass of an adult male black-gloved wallaby, killed on the road near the western boundary of Whiteman Park, was refrigerated within 5 h of its death. After 36 h in refrigeration, the digestive tract was removed and the stomach, small intestine and large intestine contents were separated. The large intestine and rectum contents could not be completely separated and were analysed together. The digestive contents were washed with water using a fine sieve to remove the digestive acids before being stored in alcohol. Epidermal tissue of the constituent plant species was obtained, stained and mounted using the methods described above.

Results

Plant resources available for herbivory

A total of 73 species were encountered in the transect samples, with mean cover ranging from more than 3% for *Patersonia occidentalis* to 0.01% for a number of species, such as *Adenanthos cygnorum*, *Arnocrinum preissii*, *Danthonia setacea* and *Oxylobium capitatum*, that were encountered only once (Table 1). The more common species included *Patersonia occidentalis*, *Xanthorrhoea preissii*, *Beaufortia elegans*, *Leucopogon conostephioides*, *Hypocalymma angustifolium* and *Alexgeorgea nitens*. Of the total species, 88% had a mean cover value less than 1%. No species was found in all 30 quadrats. *Gladiolus caryophyllaceus*, *Lyginia barbata*, *Hibbertia subvaginata* and *Patersonia occidentalis* had the highest frequency values, ranging from 85% to 62%. Of the total species, 24% were found in only a single quadrat.

Black-gloved wallaby digestive tract contents

A total of eight species (seven dicotyledons and one monocotyledon) were identified in the stomach and intestinal tract of the road-killed black-gloved wallaby

Table 1

Mean percentage cover in quadrats and percentage frequency of plant species in the 30 quadrats sampled in Whiteman Park (see text for quadrat locations).

Species	Percentage Cover	Percentage Frequency
Patersonia occidentalis	3.03	62.5
Xanthorrhoea preissii	2.95	35.0
Beaufortia elegans	2.20	32.5
Leucopogon conostephioides	2.15	37.5
Hypocalymma angustifolium	2.02	15.0
Alexgeorgea nitens	1.86	60.0
Eremaea pauciflora	1.70	22.5
Lyginia barbata	1.29	70.0
Calytrix angulata	1.25	32.5
Hibbertia subvaginata	0.93	70.0
Stirlingia latifolia	0.92	27.5
Lechenaultia floribunda	0.70	15.0
Schoenus curvifolius	0.49	40.0
Dampiera linearis	0.49	30.0
Hibbertia hypericoides	0.45	22.5
Hemiandra linearis	0.45	12.5
Conostephium pendulum	0.44	30.0
Dasypogon bromeliifolius	0.42	20.0
Scholtzia involucrata	0.36	22.5
Gompholobium tomentosum	0.36	20.0
Stylidium repens	0.35	32.5
Acacia pulchella	0.33	20.0
Hypocalymma robustum	0.31	17.5
Calytrix flavescens	0.30	22.5
Allocasuarina fraseriana	0.30	5.0
Banksia attenuata	0.25	7.5
moss	0.24	27.5
Loxocarya flexuosa	0.24	20.0
Stipa sp	0.20	15.0
Banksia ilicifolia	0.20	7.5
Melaleuca preissiana	0.18	2.5
Trachymene pilosa	0.15	32.5
Hibbertia huegelii	0.15	12.5

Table 1 (continued)

Species	Percentage Cover	Percentage Frequency
Gladiolus caryophyllaceus	0.13	85.0
Petrophile linearis	0.13	12.5
Airia sp	0.12	5.0
Bossiaea eriocarpa	0.09	17.5
Waitzia podolepis	0.09	17.5
Acacia sessilis	0.09	15.0
Jacksonia floribunda	0.08	10.0
Leucopogon polymorphus	0.08	10.0
Briza maxima	0.08	5.0
orchid spp	0.07	20.0
Eriostemon spicatus	0.06	17.5
Banksia menziesii	0.06	15.0
Drosera erythrorhiza	0.05	25.0
Pimelea sulphurea	0.05	5.0
Persoonia saccata	0.05	5.0
Daviesia triflora	0.05	2.5
Scaevola paludosa	0.05	2.5
Acacia stenoptera	0.03	2.5
Burtonia scabra	0.03	2.5
Calectasia cyanea	0.03	2.5
Hibbertia racemosa	0.03	2.5
Regelia ciliata	0.03	2.5
Ehrharta calycina	0.02	20.0
Haemodorum spicatum	0.02	17.5
Drosera macrantha	0.01	10.0
Ursinia anthemoides	0.01	7.5
Allocasuarina humilis	0.01	5.0
Hypochaeris glabra	0.01	5.0
Lepidosperma angustatum	0.01	5.0
Stylidium brunonianum	0.01	5.0
Thysanotus sp	0.01	5.0
Adenanthos cygnorum	0.01	5.0
Anizoganthos humilis	0.01	2.5
Arnocrinum preissii	0.01	2.5
Banksia grandis	0.01	2.5
Danthonia setacea	0.01	2.5
Lomandra hermaphrodita	0.01	2.5
Oxylobium capitatum	0.01	2.5
Tricoryne elatior	0.01	2.5
rhizomatous monocotyledon	0.01	2.5

Table 2

Plant species identified in the stomach, small intestine and large intestine of a road-killed black-gloved wallaby. The subjective scale of fragment abundance in the samples is rare (R), common (C), abundant (A) and not recorded (x). Unknown dicotyledons #8 and #9 were not included in the voucher collection from the study site.

Species	Stomach	Small Intestine	Large Intestine
Adenanthos cygnorum	R	R	R
Arnocrinum preisii	C	C	C
Eriostemon spicatus	C	C	C
Hovea trisperma	C	C	C
Nuytsia floribunda	R	R	R
Leucopogon conostephioides	R	R	x
dicotyledon #8	C	C	C
dicotyledon #9	C	C	C
Total Species Identified	8	8	7

(Table 2). Seven plant species were identified from all three parts of the digestive tract. *Leucopogon conostephioides* was present in very small quantities in the stomach and small intestine, but was not identified recorded for the large intestine. The similarity of species content throughout the digestive tract confirmed that faecal pellet analysis provides a sufficiently accurate indication of these plant species.

Black-gloved wallaby faecal pellets

Twenty-nine plant species were recovered from the black-gloved wallaby faeces collected at Whiteman Park (Table 3). On average, six to seven plant species were found in each pellet, and season had no effect on the number of plant species consumed. Of the 29 species consumed, 21 were positively identified using the epidermal reference collection. The remaining eight (seven dicotyledon species and one monocotyledon species) were not able to be identified to species. Three of the 21 identified species consumed were the succulent exotic *Carpobrotus edulis* and the two introduced grasses *Cynodon dactylon* and *Ehrharta calycina*. *Carpobrotus edulis* was especially common in all faecal pellets during summer and autumn, but was absent from the pellets in winter and spring. *Cynodon dactylon* is the grass used in the managed and watered lawn areas of the archery and skeet shooting ranges. *Ehrharta calycina* is especially common in disturbed areas along the roads and parking lots.

The most common native species in the black-gloved wallaby diet was *Macrozamia riedlei*, occurring in 50% of the faecal pellets analysed. *Tricoryne elatior* was found in 42% of the pellets, while *Leucopogon conostephioides*, *Nuytsia floribunda* and the unknown dicotyledon #1 were found in 33% of the pellets examined. Eleven species, including *Patersonia occidentalis*, *Conostephium pendulum* and *Mesomelaena stygia*, were found in only a single pellet. *Carpobrotus edulis*, *Cynodon dactylon*, *Nuytsia floribunda* and unknown dicotyledon #1 were the only species classed subjectively as abundant in one or more faecal pellets. The remaining 25 species were classified as either common or rare in faecal pellets. All but one of the species consumed (*Macrozamia riedlei*) belong to the class Magnoliopsida. Of these, 64% were dicotyledons and 36% were monocotyledons. This compares to the 69% dicotyledons:31% monocotyledons proportions noted for the ratio found in the vegetation survey.

Western grey kangaroo faecal pellets

Twenty-five species were represented in the faecal pellet samples of the western grey kangaroo of Whiteman Park (Table 4). An average of six plant species was found per pellet over the entire year, with no obvious seasonal pattern observed in the number of species in each sample. Of the 25 species identified in the faecal material, 20 species were identified using the epidermal reference collection. The same three exotic species consumed by the black-gloved wallabies were found in the pellets of the western grey kangaroos. *Carpobrotus edulis* was found in 42% of the pellets examined, and was common to abundant in most of the pellets in all seasons except spring. *Cynodon dactylon* was the most frequently consumed exotic species, occurring in 58% of the faecal pellets.

The tufted perennial *Alexgeorgea nitens* was the most commonly identified native species, occurring in 75% of the samples. Other native species commonly identified in

Table 3

Plant species identified in black-gloved wallaby faecal pellets collected during the four seasonal sampling periods. Three pellets were analysed during each sampling period. The subjective scale of fragment abundance in the pellet is rare (R), common (C) and abundant (A). Percentage of occurrence (%) for all sample pellets (n=12) through the year, and the total species richness in each sample pellet, are shown.

	Summer			Autumn			Winter			Spring			%
Plant Species Site	1	2	3	1	2	3	1	2	3	1	2	3	
Acacia stenoptera						R		R					17
Alexgeorgea nitens										C			8
Arnocrinum preissii								R					8
Beaufortia elegans							R	C			R		25
Carpobrotus edulis	A	A	C	R	C	C							50
Conostephium pendulum												R	8
Corynotheca micrantha		C					R						17
Cynodon dactylon	C	C	A	A	C	A	C			C	C	C	83
Dampiera linearis				R						R			17
Danthonia setacea					R		R						17
Ehrharta calycina			R								R		17
Eucalyptus marginata											R		8
Leucopogon conostephioides				R					R		C	C	33
Leucopogon sp A										C	C	C	25
Lysinema ciliatum		R											8
Macrozamia riedlei	R	R	C			R					C	R	50
Mesomalaena stygia	R												8
Nuytsia floribunda							A	R	A		R		33
Oxylobium capitatum					R			R					17
Patersonia occidentalis						R							8
Tricoryne elatior	C		C		C		C		C				42
dicotyledon #1				A	A	A				C			33
dicotyledon #2					C	R			R				25
dicotyledon #3			R										8
dicotyledon #4								C					8
dicotyledon #5								C					8
dicotyledon #6							R	R					17
dicotyledon #7						R							8
monocotyledon #1	C		C			C							25
Total Species Richness	6	5	7	5	7	9	7	8	4	5	8	5	

the western grey kangaroo faecal material included *Leucopogon* sp A, *Leucopogon conostephioides, Danthonia setacea, Corynotheca micrantha* and *Dampiera linearis.* Of the 24 angiosperm species in the diet, 58% were dicotyledonous species and 42% were monocotyledonous species. As for the black-gloved wallaby, the faecal pellets of the western grey kangaroo tended to contain a number of species of plants with few being in abundant concentrations.

Diet overlap

Both the black-gloved wallaby and the western grey kangaroo were versatile feeders, consuming a wide range of plant species. There was considerable overlap in the feeding preferences, with 18 species consumed by both macropods. Species that frequently appeared in the faecal pellets of both animals included *Carpobrotus edulis, Cynodon dactylon, Leucopogon conostephioides* and *Leucopogon* sp A. Some species were in a large proportion of the faecal pellets from one macropodid, but only in one or two pellets from the other species. For example, *Alexgeorgea nitens* occurred in 75% of the western grey kangaroo faecal pellets but only 8% of the black-gloved wallaby faecal pellets. Other species such as *Ehrharta calycina, Oxylobium capitatum* and *Patersonia occidentalis,* were in only one or two faecal pellets from both macropods.

Food resource characteristics

The plant species consumed by black-gloved wallabies had a mean field cover of 0.43% compared to a mean cover of 0.24% for those not consumed, but the difference was not significant (Table 5). Similarly, mean percentage covers of the consumed and non-consumed species were not significantly different for the diet selected by the western grey kangaroos. Of the thirteen chemical constituents considered, there were no significant differences observed between the mean content in plants eaten and those not eaten by the black-gloved wallaby for any of the comparisons. Results were similar for the western grey kangaroo, except nitrate in dietary resources was significantly higher in the plants chosen compared to the plants avoided. Moisture content was not significantly different for plant species consumed and avoided, for either macropod. The ash content of the plants chosen and avoided were also not significantly different for the diets of either species.

Table 4

Plant species identified in western grey kangaroo faecal pellets collected during the four seasonal sampling periods. Three pellets were analysed during each sampling period. The subjective scale of fragment abundance in the pellet is rare (R), common (C) and abundant (A). Percentage of occurrence (%) for all sample pellets (n=12) through the year, and the total species richness in each sample pellet, are shown.

Plant Species	Site	Summer 1	Summer 2	Summer 3	Autumn 1	Autumn 2	Autumn 3	Winter 1	Winter 2	Winter 3	Spring 1	Spring 2	Spring 3	%
Adenanthos cygnorum		R		C				R						25
Alexgeorgea nitens		C		C	C	R	C	C		C	C		C	75
Bossiaea eriocarpa								R			R			17
Carpobrotus edulis		C		C		C	C			A				42
Conostephium pendulum			C								C			17
Corynotheca micrantha			R						R		C		R	33
Cynodon dactylon		C	C	C		C			A		C		C	58
Dampiera linearis			R	R		R	C							33
Danthonia setacea								C		C	C	C	C	42
Ehrharta calycina		R			A									17
Jacksonia furcellata											R			8
Leucopogon conostephioides			C			C		C		C				33
Leucopogon sp A					C			C	R		C	C	R	50
Loxocarya flexuosa												R		8
Macrozamia riedlei								R		C				17
Nuytsia floribunda		C												8
Oxylobium capitatum			C				R							17
Patersonia occidentalis												R		8
Stipa sp A												R		8
Tricoryne elatior			C											8
dicotyledon #1		C				C								17
dicotyledon #4				R										8
dicotyledon #7				C		C	C		C					33
dicotyledon #8												R		8
monocotyledon #2											R			8
Total Species Richness		7	7	7	3	7	5	7	4	5	9	6	5	

Table 5

Characteristics of species chosen (those positively identified in faecal material) and those avoided (those not confirmed in faecal material) in the diets of the black-gloved wallaby and western grey kangaroo populations in Whiteman Park. NS is not significant.

	Black-gloved wallaby				Western grey kangaroo			
Characteristic	Chosen	Avoided	t or χ^2	Sig. Diff.	Chosen	Avoided	t or χ^2	Sig. Diff.
Field vegetation								
Field Cover (%)	0.43 ± 0.18	0.24 ± 0.06	1.33	NS	0.42 ± 0.19	0.25 ± 0.06	1.07	NS
Plant Frequency (%)	12.81 ± 3.94	11.53 ± 1.88	0.29	NS	14.25 ± 4.48	11.24 ± 0.70	0.70	NS
Chemical, moisture and total ash contents								
Calcium (%)	0.66 ± 0.11	0.75 ± 0.06	-0.76	NS	0.61 ± 0.12	0.76 ± 0.06	-1.19	NS
Chloride (%)	0.75 ± 0.03	0.71 ± 0.09	0.17	NS	0.99 ± 0.38	0.64 ± 0.08	1.42	NS
Copper (ppm)	5.17 ± 0.48	6.18 ± 0.61	-0.96	NS	5.49 ± 0.49	6.03 ± 0.59	-0.49	NS
Iron (ppm)	148.40 ± 36.20	117.00 ± 14.70	0.96	NS	174.23 ± 40.07	110.73 ± 14.08	1.89	NS
Magnesium (%)	0.20 ± 0.03	0.25 ± 0.02	-1.35	NS	0.19 ± 0.04	0.25 ± 0.02	-1.45	NS
Manganese (ppm)	46.12 ± 6.89	71 ± 94	-1.62	NS	61.55 ± 10.50	66.05 ± 8.75	-0.26	NS
Nitrate (ppm)	33.18 ± 9.10	27.14 ± 1.34	1.02	NS	38.42 ± 10.27	25.82 ± 1.32	2.07	P<0.05
Nitrogen (%)	1.10 ± 0.09	1.17 ± 0.07	-0.54	NS	1.16 ± 0.12	1.15 ± 0.07	0.09	NS
Phosphorus (%)	0.04 ± 0.00	0.05 ± 0.01	-0.88	NS	0.05 ± 0.01	0.05 ± 0.01	0.25	NS
Potassium (%)	0.58 ± 0.09	0.55 ± 0.09	0.22	NS	0.63 ± 0.10	0.53 ± 0.06	0.82	NS
Sodium (%)	0.31 ± 0.10	0.25 ± 0.03	0.17	NS	0.34 ± 0.11	0.25 ± 0.03	1.15	NS
Sulphur (%)	0.19 ± 0.02	0.24 ± 0.02	-1.23	NS	0.21 ± 0.02	0.24 ± 0.02	-0.72	NS
Zinc (ppm)	30.73 ± 5.30	43.72 ± 8.78	-0.87	NS	40.89 ± 6.06	40.04 ± 8.40	0.05	NS
Moisture Content (%)	52.25 ± 2.60	55.83 ± 1.55	1.17	NS	51.86 ± 3.18	55.72 ± 1.46	1.18	NS
Ash Content (%)	3.75 ± 0.73	4.60 ± 0.43	-0.98	NS	3.58 ± 0.87	4.60 ± 0.41	1.11	NS

Table 5 (continued)

Characteristic	Black-gloved wallaby				Western grey kangaroo			
	Chosen	Avoided	t or χ^2	Sig. Diff.	Chosen	Avoided	t or χ^2	Sig. Diff.
Morphological features								
Apex Type	—	—	12.08	NS	—	—	12.57	NS
Apex soft or hard	—	—	0.51	NS	—	—	0.79	NS
Glands present or absent	—	—	1.31	NS	—	—	6.55	P<0.05
Consistency	—	—	5.22	NS	—	—	6.60	NS
Adaxial tomentosity	—	—	2.30	NS	—	—	2.54	NS
Abaxial tomentosity	—	—	2.64	NS	—	—	5.30	NS

The morphological features of the plants selected and avoided by the two macropods were not generally different (Table 5). The type of leaf apex, whether the apex was soft or hard, the presence or absence of glands, leaf consistency, and adaxial and abaxial tomentosity, had no relationship to the types of plants consumed by black-gloved wallabies. Western grey kangaroos, however, avoided plants with leaf glands, notably the Myrtaceae. Other morphological characteristics had no relationship to the choices made by the western grey kangaroos.

Discussion

Central to the study of animal ecology is the use a herbivore makes of its environment, specifically the types of plants it consumes in the different habitats it occupies. It is not only worthwhile knowing what a herbivore eats, but also when and how much is consumed, the availability of the resource and the nutritional value of the plant to the animal (Free *et al.* 1970). It is also advantageous to understand the relationship between a herbivore and other species with which it co-exists, particularly the level of competition for shared resources. When shared resources are in limited supply, competition will eventually lead to the more successful competitor excluding the other. Management of animal populations in restricted range habitats, therefore, requires a wide array of information.

In this study, the black-gloved wallabies of Whiteman Park consumed a wide range of species, generally in moderate or small amounts rather than a few species in large amounts. However, *Carpobrotus edulis*, *Cynodon dactylon*, and *Nuytsia floribunda* were found in abundant amounts in the faeces. The succulent *Carpobrotus edulis* and the lawn *Cynodon dactylon* were the most abundantly consumed species in the drier seasons, a time when free-standing water was not readily available in the study area. The hemi-parasitic *Nuytsia floribunda*, the only species noted as abundant in the faecal samples of winter samples, might also be a likely source of moisture due to its ability to absorb water from neighbouring plants. The black-gloved wallaby has been noted by Christensen (1983) to be able to survive without free water. The Whiteman Park population of black-gloved wallabies would be especially well served with these moisture-rich plants for their source of water.

The western grey kangaroos of Whiteman Park showed a similar tendency as black-gloved wallabies to consume a wide variety of plant species in limited amounts. As for black-gloved wallabies, these larger marsupials consumed abundant quantities of the exotic, succulent *Carpobrotus edulis* and the lawn grass *Cynodon dactylon* among the 25 dietary plant species. As in previous studies (Halford *et al.* 1984b; Shepherd *et al.* 1997), it appears that the western grey kangaroo is a versatile feeder, consuming a wide variety of plant species and plant types.

Consumption of a wide variety of plant species is seen both as an adaptation to the prevention of adverse effects from plant poisons (Howe & Westley 1988), but also a necessity, as the plant species of Whiteman Park have very low cover percentages. A mixed species diet is therefore required to provide sufficient energy for survival. Limited grazing and browsing on a range of plant species is also of significance to the management of Whiteman Park, as herbivore pressure on any individual plant species is not likely to result in local extinction.

Hume's (1982) review of marsupial nutritional requirements concludes that potoroid and small macropod species generally ingest plants of higher nutritive value than do larger (greater than 10 kg) macropods. A relationship between body size and nutritive value of preferred diets has also been reported for eutherian herbivores (Demment & Van Soest 1985). Total energy requirement of animals tends to increase with increasing body mass, but at a progressively slow rate. Thus, although larger animals require more total energy (kJ d^{-1}), small animal require more energy relative to body mass (kJ kg^{-1} d^{-1}) (Freudenberger *et al.* 1989). It may be that subtle differences in food perception are responsible for the observed differences in selection. A smaller animal may be capable of distinguishing food types on a finer scale than larger animals (Norbury & Sanson 1992). In this study, however, the measured chemical constituents and the range of morphological features described for leaves between chosen and avoided species were not different. It is believed that different plants within a plant community have varying palatabilities for grazing sheep (Krueger *et al.* 1974). Although taste is of primary importance in diet selection in sheep, smell, sight and touch also play a role, although they may be of minor importance. Unfortunately, such information is not known for the majority of herbivores, including macropods. Until it is known whether senses such as taste, smell, sight and touch significantly affect a macropod's food perception, and if so to what extent, problems will remain as to whether measured food availability is the same as perceived food availability.

Halford *et al.* (1984b) showed that plants potentially high in nitrogen (*i.e.* legume species) were preferentially browsed by western grey kangaroos in a *Eucalyptus wandoo*-grass pasture landscape near Bakers Hill. The results in the present study indicated that nitrate levels of selected species was higher than avoided species. Although an ability to select plant species of high nitrate condition or high protein level would be a valuable asset for the herbivore, we feel this finding should be viewed with caution for a number of reasons. Firstly, it is doubtful that western grey kangaroos would not obtain enough nitrogen in their normal diet and, therefore, seek out plants high in nitrates. Even if they did, kangaroos would need the appropriate microbial symbionts in their digestive systems to convert the nitrates to nitrites, so they could be assimilated. We are not aware if this species has such microbial symbionts. Secondly, it is also doubtful if these kangaroos can perceive parts per million concentration differences in leaf content of nitrates. Thirdly, due to the number of comparisons analysed, it could be expected that one comparison might be falsely indicated as different. Further detailed comparisons would be necessary to confirm the ability of this marsupial herbivore to select high nitrate containing plants.

Western grey kangaroos appear to avoid plant species with oil glands. Black-gloved wallabies, on the other hand, consumed a number of species with oil glands, but only in small or moderate amounts. The evolutionary significance of oil glands in the Myrtaceae and Rutaceae families is uncertain, but it is possible that they play a role in the prevention of herbivory. However, the detection of diet selection by herbivores is a very complicated task. Many factors must be considered, such as positive nutritional elements, negative compounds, such as lignin, tannins, pectins and toxin, water requirements and morphological characteristics of leaves, stems and branches. Considering each of these factors separately can give clues to diet selection, but an ideal method of analysis would simultaneously take all factors into consideration for each plant species. For example, a plant species may have high positive nutrients and high water content, but the present of pungent spines or toxins may render the plant inedible for certain herbivore species. Searching for trends in the light of specific characters may, therefore, be an oversimplified and inappropriate method of determining diet selection. Although the use of more sophisticated multivariate statistical techniques might lend further knowledge on diet selection, the characters are not independent of one another, and therefore, this statistical technique is invalid on mathematical grounds.

This study of dietary preference in black-gloved wallabies and western grey kangaroos in Whiteman Park has confirmed their polyphagous nature. The diversity of plant species in Whiteman Park provides a wide range of dietary choices for both herbivores. Competitive exclusion is not considered to be cause for concern as the vegetation of Whiteman Park provides a large number of acceptable food resources for both animals. The provision of significant numbers of high moisture content plants would favour the continued survival of both species, but especially the black-gloved wallabies that require plant-derived moisture rather than free-water sources.

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References

Anon. 1989 Ecological Studies - Whiteman Park. Mattiske and Associates Report. The Western Australian State Planning Commission. Perth, Western Australia.

Anon 1992 Gnangara Mound Vegetation Stress Survey. Results of Investigation. The Water Authority of Western Australian, Leederville, Western Australia.

Arnold G W 1991 Whiteman Park Fauna Survey. CSIRO Division of Wildlife and Ecology, Perth.

Bell D T 1994 Plant community structure in southwestern Australia and aspects of herbivory, seed dispersal and pollination. In: Plant-Animal Interactions in Mediterranean Ecosystems (eds M Arianoutsou & R H Groves). Kluwer Academic Publishers, Dordrecht, 63-70.

Bettenay E, McArthur W M & Hingston F J 1960 The soil associations of part of the Swan Coastal Plain, Western Australia. Soil and Land Use Series, 35. CSIRO, Division of Soils, Perth.

Christensen P 1983 Western brush wallaby. In: The Australian Museum Complete Book of Australian Mammals (ed R Strahan). Angus and Robertson, Sydney, 235.

Demment M W & Van Soest P J 1985 A nutritional explanation for body size patterns of ruminant and non-ruminant herbivores. American Naturalist 125:641-672.

Free J C, Hansen R M & Sims P L 1970 Estimating dry weight in food plants in faeces of herbivores. Journal of Range Management 23:300-302.

Freudenberger D O, Wallis I R & Hume I D 1989 Digestive adaptations of kangaroos, wallabies and rat-kangaroos. In: Kangaroos, Wallabies and Rat-Kangaroos (ed G Grigg, P Jarmann & I Hume). Surrey Beatty & Sons, Sydney, 179-187.

Halford D A, Bell D T & Loneragan W A 1984a Epidermal characteristics of some Western Australian wandoo-woodland species for studies of herbivore diets. Journal of the Royal Society of Western Australia 66:111-118.

Halford D A, Bell D T & Loneragan W A 1984b Diet of the western grey kangaroo (*Macropus fuliginosus* Desm.) in a mixed pasture-woodland habitat of Western Australia. Journal of the Royal Society of Western Australia 66:119-128.

Howe F H & Westley L C 1988 Ecological Relationships of Plants and Animals. Oxford University Press, Oxford.

Hume I D 1982 Digestive Physiology and Nutrition of Marsupials. Cambridge University Press, Cambridge.

Jain K K 1976 Hydrogen peroxide and acetic acid for preparing epidermal peels from conifer leaves. Stain Technology 51:202-204.

Krueger W C, Laycock W A & Price D A 1974 Relationships of taste, smell, sight and touch to forage selection. Journal of Range Management 27:258-262.

Norbury G L & Sanson G D 1992 Problems with measuring diet selection of terrestrial mammalian herbivores. Australian Journal of Ecology 17:1-7.

Poole W E 1983 Western grey kangaroo. In: The Australian Museum Complete Book of Australian Mammals (ed R Strahan). Angus and Robertson, Sydney, 248-249.

Priddel D 1986 The diurnal and seasonal patterns of grazing of the red kangaroo, *Macropus rufus*, and the western grey kangaroo, *M. fuliginosus*. Australian Wildlife Research 13:113-120.

Shepherd K A, Wardell-Johnson G W, Loneragan W A & Bell D T 1997 Dietary of herbivorous marsupials in a *Eucalyptus marginata* forest and their impact on the understorey vegetation. Journal of the Royal Society of Western Australia 80:47-54.

Storr G M 1961 Microscopic analysis of faeces, a technique for ascertaining the diet of herbivorous mammals. Australian Journal of Biological Sciences 14:157-164.